

APPENDIX E

Development of COC Depletion Estimates from LNAPL in the Vadose Zone

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E-1.0 INTRODUCTION

Appendix E describes the methodology, procedures and calculations employed to develop the mass reduction model predicting the trend of total petroleum hydrocarbons (TPH), benzene, and methyl tert-butyl ether (MTBE) mass reduction resulting from operation of the soil vapor extraction (SVE) system located in the off-site source area.

E-2.0 ESTIMATION OF SVE MASS EXTRACTION PERFORMANCE

An SVE system has operated at the Mission Valley Terminal from November 1999 to the present. The initial system consisted of a 250 standard cubic feet per minute (scfm) SVE system and thermal oxidation vapor abatement system. In September 2001, this system was replaced with a 1,000-scfm SVE system with a thermal/catalytic oxidation vapor abatement system. The SVE systems have extracted soil vapors from extraction wells located in both the on-site and off-site source areas. As part of routine system performance monitoring, the total extracted soil vapor entering the SVE system has been regularly monitored for flow rate and volatile organic compound (VOC) concentration. Currently, the total system influent flow rate is monitored by the SVE system's transmitting Magnehelic® differential pressure gauge and pitot tube installation, which is calibrated to deliver readings in standard cubic feet per minute. VOC concentrations are measured using a field lower explosive limit (LEL) meter calibrated with a propane standard.

Data from routine monitoring events were compiled and reviewed to select data points that are representative of steady-state operation. The mass extraction rate of VOCs has been calculated using the following equation:

$$F_M = \frac{C}{10^6} \times \frac{Q}{R} \times \frac{P_{atm}}{T_{vapor}} \times MW_{avg} \times \frac{28.31L}{1\text{ft}^3} \times \frac{1\text{lb}}{454\text{grams}} \times \frac{1440\text{min}}{\text{day}} \quad (\text{E.1})$$

Where:

- F_M = Measured Mass Extraction Rate (pounds of VOC per day, lbs/d)
- C = Concentration (ppmv)
- Q = Volumetric flow rate (standard cubic feet per minute)
- R = Ideal gas constant (L-atm/mol-°K)
- P_{atm} = Atmospheric pressure (atm)
- T_{vapor} = Vapor temperature (°K)
- MW_{avg} = Average molecular weight (g/mole)
- t = Time of system operation (min)

The mass of VOCs extracted was estimated assuming ideal gas behavior. Additionally, a correlation factor between field measurements and analytical laboratory data has been periodically determined. VOC concentrations have been an average of 146 times the %LEL reading, with most recent correlation at approximately 110 times the %LEL reading. Using this correlation factor, the volumetric concentration (i.e., VOC in parts per million by volume [ppmv]) has been calculated from the %LEL measurements taken as part of routine monitoring.

The network of vapor extraction wells has gradually expanded over the life of the SVE system, with new wells brought online at different times. To properly account for the changing number of extraction wells in analysis of historical data, the wells have been subdivided into groups that have the same operational time intervals. These groupings are defined in order to facilitate interpretation of historical data and are only relevant to the analysis described herein. Well Group I consists of on-site extraction wells RW-1 and RW-2, which were initially brought online in November 1999 and were operated until June 2003. Well Group II consists of off-site extraction well RW-5, which was brought online in August 2000 and was operated until November 2003. Well Group III consists of off-site extraction wells RW-3, RW-4, RW-6, and RW-7, which were brought online in September 2001 and operated until November 2003. Well Group IV consists of off-site extraction wells RW-10 through RW-20, which were operational from June 2003 to November 2003 and were installed as part of the Phase I SVE system expansion.

The mass extraction rates for each of the four Well Groups were simplified by representing the rates as exponential decay curves defined by the following equation:

$$F = ae^{-bt} \quad (\text{E.2})$$

Where:

F = Mass Extraction Rate (lbs/d)

a = Rate Constant (lbs/d)

b = Time Constant (day⁻¹)

t = Time (day)

The mass extraction rate decay curve for each individual Well Group was summed together over the periods in which they were operational to represent a total mass extraction rate:

$$F_T = \sum_{i=1}^4 a_i e^{-b_i(t-t_{0i})} \quad (\text{E.3})$$

Where:

F_T = Total Theoretical Mass Extraction Rate (lbs/d)

i = Well Groups index [1 through 5 (I through V)]

- a_i = Rate Constant (lbs/d) for Well Group i
 b_i = Time Constant (day $^{-1}$) for Well Group i
 t_{0i} = Time (day) Well Group i comes online

Equation E.3 was fitted to the total measured mass extraction rates using a least-squares regression analysis that concurrently determined the best-fit values for each Well Group's rate and time constants, a_i and b_i . While the resulting time constants can be directly compared, the rate constant must be normalized according to the number of wells in each Well Group before values can be evaluated. The analysis determined the normalized (per-well) rate and time constants for Well Group I to be 200 pounds per day (lbs/d) and 4.19E-03 day $^{-1}$, respectively. Values for Well Group II are 105 lbs/d and 1.30E-03 day $^{-1}$. Values for Well Group III are 85 lbs/d and 7.95E04 day $^{-1}$. Values for Well Group IV are 53 lbs/d and 3.61E-03 day $^{-1}$. The average rate constant and time constant for the off-site Well Groups (i.e., not including on-site Well Group I) is 81 lbs/d and 1.90E-03 day $^{-1}$, respectively. Values for Well Group I were not included when calculating the off-site average because the wells are located on-site and may be influenced by location-specific characteristics that are not representative of the off-site area.

The compiled field data and calculated mass extraction data are presented in Table E-1 of this appendix. The measured mass extraction data and the best-fit mass extraction rate decay curve are presented as Figure E-1 of this appendix.

E-3.0 BENZENE AND MTBE MASS FRACTIONS IN EXTRACTED SOIL VAPOR

Extracted soil vapor has been sampled from off-site extraction wells as part of ongoing SVE system performance testing. Samples were collected between April and November 2003 from the Phase I expansion extraction wells RW-10 through RW-20 and the Phase II expansion wells RW-22 through RW-34. Samples collected in Tedlar bags were submitted to a fixed laboratory for analysis of volatile fuel hydrocarbons (C₆-C₁₂) with BTEX/MTBE by EPA Method 8015B/8021B. The mass fraction of benzene and MTBE relative to total volatile fuel hydrocarbons was calculated for each sample. A total of 74 samples were used to calculate the arithmetic average mass fraction as well as the 97.5% lower confidence limit (LCL) mass fraction. The results indicate extracted soil vapors in the off-site source area have an average benzene mass fraction in soil vapor of 0.028 with a 97.5% LCL of 0.025. The average MTBE mass fraction in soil vapor is 0.007 with a 97.5% LCL of 0.005. The 97.5% LCL is evaluated as described for the upper confidence limit in Appendix C, with the exception that twice the standard error is subtracted from the mean. The use of the arithmetic mean and the 97.5% LCL (as calculated) to describe the likely range of constituent mass fractions implies the assumption that the data are normally distributed. However, 53% of the MTBE data is below the detection limit, so it is not possible to accurately test the datasets for non-normality. Further, the assumption of a value of one-half the detection limit for these data may affect the calculated mean and UCL non-conservatively. Tests for non-normality suggest that the assumption of normality is not inappropriate for the benzene data.

Laboratory analytical results for the soil vapor analyses and mass fraction calculations are summarized in Table E-2 of this appendix. Laboratory analytical reports have been previously presented in the Remediation System Technical Evaluation Report (LFR. 2003) and Remediation System Continued Technical Evaluation Report (LFR. 2004).

E-4.0 DEVELOPMENT OF THE MASS REDUCTION MODELS

Two mass reduction models have been developed to approximate the time necessary to deplete the mass of TPH, benzene, and MTBE from the off-site residual light nonaqueous phase liquid (LNAPL) source to meet clean-up targets, which are documented in Appendix D. This section describes the postulation, methodology and results of a Best Estimate Mass Reduction Model and a Conservative Estimate Mass Reduction Model. The model estimates the mass extraction rates over time for TPH, benzene, and MTBE as a result of SVE.

The integral of Equation E.2 over time gives the total mass of VOC removed by SVE at any given time, t . Additionally, the mass of benzene or MTBE removed by SVE can be determined by applying the estimated mass fraction of benzene or MTBE in extracted soil gas as a constant to this equation. Therefore the general equation for TPH, benzene, or MTBE mass removed by a single SVE well is given by:

$$M_T = f_M \int_0^t ae^{-bt} dt \quad (\text{E.4})$$

Where:

M_T = Total Estimated Mass Extracted (pounds)

f_M = Mass Fraction of Compound in Soil Vapor

The fully expanded off-site SVE system will include all extraction wells from Well Groups II through IV as well as the 12 new Phase II expansion extraction wells (RW-22 through RW-34) grouped here as Well Group V, which have not been actively operated to date. Well Groups II through IV have been operating for some length of time and as such will not perform at the same efficiency that the “new” wells in Well Group V can be expected to achieve. For this reason, Equation E.4 cannot be directly applied to all Well Groups without adjusting the time variable to account for historical operation and mass extraction. The adjustments are needed to avoid overestimating the mass removal contribution provided by historically operational extraction wells. Therefore, the mass of TPH, benzene or MTBE remaining after future mass extraction by the fully expanded SVE system in the off-site area is given by the following equation:

$$M_R = M_I + f_M \sum_{i=2}^5 \left[N_i \times a_i \left(\frac{e^{-b_i(t+t_i)} - 1}{-b_i} \right) - m_i \right] \quad (\text{E.5})$$

Where:

- M_R = Mass of Compound Remaining in Vadose Zone (pounds)
 M_I = Current Mass Estimate of Compound in Vadose Zone (pounds)
 N_i = Number of Wells in Well Group i
 t_i = Historical Operating Time (days) in Well Group i , Adjustment
 m_i = Historical Mass Removed (pounds) in Well Group i , Adjustment

E-4.1 Best Estimate Mass Reduction Model

The Best Estimate Mass Reduction Model predicts the time necessary to achieve sufficient mass depletion of TPH, benzene, and MTBE such that clean-up milestones are met, assuming best estimate input values. In this model the current mass estimate of TPH, benzene, and MTBE in the vadose zone, M_i , was taken to be the calculated mean values of 602,000 pounds, 4,710 pounds, and 1,270 pounds, respectively. The mass fractions of benzene and MTBE in extracted soil vapor, f_M , were assumed to be the average values of 0.028 and 0.007, respectively. The rate and time constants, a and b , for each Well Group were taken to be the Well Group-specific estimated values, with Well Group V assigned the off-site average values. This calculation was carried out over time until sufficient mass depletion of benzene and MTBE had occurred to meet target levels. Target levels for this model are defined as the mass fractions of benzene and MTBE remaining in the soil that correspond to the mass flux target. Therefore, the mass fraction of benzene and MTBE relative to the decreasing mass of TPH in the vadose zone is calculated at each point in time to identify when clean-up milestones are met.

The Best Estimate Mass Reduction Model predicts benzene mass fraction target levels of 4.8×10^{-5} are achieved at 116 days of operation and MTBE mass fraction target levels of 7.6×10^{-6} are achieved at 134 days of operation. These predictions assume mass depletion rates adhere to the empirical mass extraction estimates calculated here. The model input values and results are presented in Table E-3 of this appendix. The mass reduction model is shown in Figure E-2 of this appendix.

E-4.2 Conservative Estimate Mass Reduction Model

The Conservative Estimate Mass Reduction Model predicts the time necessary to achieve sufficient mass depletion of TPH, benzene, and MTBE on the vadose zone such that clean-up milestones are met, assuming conservative 97.5% confidence limit input values. Conservative input values were selected to present a prediction with a high degree of confidence. In this model the current mass estimate of TPH, benzene, and MTBE in the vadose zone, M_i , was taken to be the calculated 97.5% upper confidence limit values of 759,600 pounds, 7,620 pounds, and 2,290 pounds, respectively. The mass fractions of benzene and MTBE in extracted soil vapor, f_M , were assumed to be the 97.5% LCL values of 0.025 and 0.005, respectively. The rate and time constants, a and b , for each Well Group were taken to be the Well Group-specific calculated values, with Well Group V assigned the lowest observed off-site rate constant and the largest observed

off-site time constant. This calculation was carried out over time until sufficient mass depletion of benzene and MTBE had occurred to meet clean-up milestones, as described in Best Estimate Mass Reduction Model.

The Conservative Estimate Mass Reduction Model predicts benzene mass fraction target levels are achieved at 387 days of operation and MTBE mass fraction target levels are achieved at 947 days of operation. These predictions assume mass depletion rates adhere to the empirical mass extraction estimate calculated here. The model input values and results are presented in Table E-4 of this appendix. A graphical representation of the estimated mass reduction model over time is presented as Figure E-3 of this appendix.

E-5.0 ESTIMATION OF EQUILIBRIUM VAPOR CONCENTRATIONS AT MASS FLUX TARGET LEVELS

Further analysis was conducted to estimate the vapor concentrations of benzene and MTBE in the vadose zone in after active off-site remedial activities cease and concentrations of chemicals of concern (COCs) in the off-site residual LNAPL area are reduced to levels that achieve the mass flux targets. Henry's Law was used to estimate the equilibrium vapor phase concentrations for the COCs. The calculated target effective solubilities of benzene and MTBE are assumed to be 87 micrograms per liter ($\mu\text{g/l}$) and 417 $\mu\text{g/l}$, respectively (Appendix D). Henry's Constants for benzene and MTBE are assumed to be 0.22 and 0.055, respectively (Moyer and Kostecki 2003). The vapor phase concentrations were calculated according to the following relationship:

$$C_v = HC_L \times R \times \frac{T_{vapor}}{P_{atm}} \times \frac{10^3}{MW_{COC}}$$

Where:

C_v = Concentration in the vapor phase (ppbv)

H = Henry's Constant (dimensionless)

C_L = Concentration in the Liquid Phase ($\mu\text{g/l}$)

MW_{COC} = Molecular Weight of COC (g/mole)

Results indicate the target near-groundwater vapor concentration at mass flux target levels is 5,990 parts per billion (ppbv) for benzene and 6,362 ppbv for MTBE.

E-6.0 REFERENCES

LFR. 2003. Remediation System Technical Evaluation Report, Mission Valley Terminal, San Diego, California. July 8.

LFR. 2004. Remediation System Continued Technical Evaluation Report, Mission Valley Terminal, San Diego, California. January 23.

Moyer, Ellen E. and Paul T. Kostecki. 2003. MTBE Remediation Handbook. Amherst Scientific Publishers, Amherst, MA.

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group I	11/03/99	1	250	8,710	873
- RW-1 & RW-2 Brought Online	11/04/99	2	250	8,014	803
	11/05/99	3	250	7,665	768
	11/06/99	4	250	4,529	454
	11/07/99	5	250	2,439	244
	11/08/99	6	250	1,045	105
	11/09/99	7	250	697	70
	11/17/99	10	250	8,710	873
	11/18/99	11	250	8,710	873
	11/19/99	12	250	7,665	768
	11/20/99	13	250	4,529	454
	11/21/99	14	250	1,742	175
	11/22/99	15	250	364	36
	11/23/99	16	250	364	36
	11/24/99	17	250	4,007	401
	11/25/99	18	250	5,099	511
	11/26/99	19	250	3,278	328
	11/27/99	20	250	1,093	109
	11/28/99	21	250	182	18
	11/29/99	22	250	728	73
	11/30/99	23	250	4,007	401
	12/01/99	24	260	1,744	182
	12/02/99	25	265	581	62
	12/03/99	26	250	7,267	728
	12/04/99	27	149	7,267	434
	12/05/99	28	147	6,976	411
	12/06/99	29	145	5,232	304
	12/07/99	30	185	8,710	646
	12/08/99	31	149	8,361	499
	12/09/99	32	147	8,710	513
	12/10/99	33	145	6,271	364
	12/11/99	34	149	8,710	520
	12/12/99	35	147	8,710	513
	12/13/99	36	106	1,742	74
	12/14/99	37	105	348	15
	12/15/99	38	104	348	15
	12/16/99	39	118	3,136	148
	12/17/99	40	140	3,484	196
	12/18/99	41	108	1,742	75
	12/19/99	42	112	3,136	141
	12/20/99	43	150	6,619	398
	12/21/99	44	146	4,529	265
	12/22/99	45	143	2,914	167
	12/23/99	46	143	1,093	63
	12/24/99	47	141	364	21
	12/25/99	48	139	364	20
	12/26/99	49	137	364	20
	12/27/99	50	136	364	20
	12/28/99	51	173	9,106	631
	12/29/99	52	171	7,649	524
	12/30/99	53	171	7,649	524

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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group I (cont)	12/31/99	54	169	7,649	518
	01/01/00	55	169	3,784	256
	01/02/00	56	169	3,784	256
	01/03/00	57	171	3,585	246
	01/04/00	58	170	3,585	244
	01/05/00	59	169	3,187	216
	01/06/00	60	170	3,187	217
	01/07/00	61	169	3,187	216
	01/08/00	62	169	2,988	202
	01/09/00	63	168	2,988	201
	01/10/00	64	168	2,988	201
	01/11/00	65	166	2,788	186
	01/12/00	66	165	2,988	198
	01/13/00	67	189	2,988	226
	01/14/00	68	211	2,988	253
	01/18/00	70	182	4,382	320
	01/19/00	71	187	3,983	299
	01/20/00	72	187	3,983	299
	01/21/00	73	187	3,983	299
	01/22/00	74	188	3,983	300
	01/23/00	75	187	3,983	299
	01/24/00	76	187	3,983	299
	01/25/00	77	133	4,979	265
	01/26/00	78	131	4,581	241
	01/29/00	81	149	5,378	321
	01/30/00	82	150	5,577	335
	01/31/00	83	171	4,780	328
	02/01/00	84	172	6,093	420
	02/02/00	85	157	5,463	344
	02/03/00	86	169	6,093	413
	02/04/00	87	171	6,093	418
	02/05/00	88	169	6,303	427
	02/06/00	89	170	6,093	415
	02/07/00	90	173	6,093	423
	02/08/00	91	173	6,093	423
	02/09/00	92	175	6,093	427
	02/10/00	93	225	1,975	178
	02/11/00	94	225	1,786	161
	02/12/00	95	225	1,807	163
	02/13/00	96	225	1,786	161
	02/14/00	97	224	1,912	172
	02/15/00	98	224	1,891	170
	02/16/00	99	225	1,786	161
	02/17/00	100	172	4,412	304
	02/18/00	101	175	4,412	309
	02/19/00	102	171	4,622	317
	02/20/00	103	173	4,412	306
	02/21/00	104	175	4,412	309
	02/22/00	105	174	4,412	308
	02/23/00	106	174	4,622	322
	02/24/00	107	176	4,622	326

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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
<u>Well Group I (cont)</u>	02/25/00	108	175	4,622	324
	02/26/00	109	175	4,622	324
	02/27/00	110	174	4,622	322
	02/28/00	111	174	4,622	322
	02/29/00	112	175	4,622	324
	03/01/00	113	175	3,313	232
	03/02/00	114	174	3,313	231
	03/03/00	115	174	3,313	231
	03/04/00	116	174	3,313	231
	03/05/00	117	175	3,162	222
	03/06/00	118	175	3,313	232
	03/07/00	119	176	3,162	223
	03/08/00	120	175	3,313	232
	03/09/00	121	176	3,162	223
	03/10/00	122	174	3,313	231
	03/11/00	123	172	3,313	228
	03/12/00	124	173	3,313	230
	03/13/00	125	171	3,313	227
	03/14/00	126	171	3,464	237
	03/15/00	127	170	3,464	236
	03/16/00	128	170	3,313	226
	03/17/00	129	170	3,464	236
	03/18/00	130	169	3,464	235
	03/19/00	131	170	3,313	226
	03/20/00	132	170	3,313	226
	03/21/00	133	172	3,162	218
	03/22/00	134	177	3,012	214
	03/23/00	135	139	3,464	193
	03/24/00	136	136	3,614	197
	03/25/00	137	137	3,464	190
	03/31/00	140	160	3,614	232
	04/01/00	141	140	3,494	196
	04/02/00	142	142	3,494	199
	04/03/00	143	140	3,348	188
	04/04/00	144	140	3,057	172
	04/05/00	145	141	2,912	165
	04/06/00	146	141	2,766	156
	04/07/00	147	142	2,766	157
	04/08/00	148	212	3,494	297
	04/09/00	149	213	3,494	298
	04/10/00	150	214	3,494	300
	04/11/00	151	215	3,494	301
	04/12/00	152	214	3,639	312
	04/13/00	153	206	3,639	301
	04/14/00	154	212	3,494	297
	04/15/00	155	213	3,494	298
	04/16/00	156	214	3,494	300
	04/17/00	157	216	3,494	302
	04/18/00	158	217	3,494	304
	04/19/00	159	214	3,785	325
	04/20/00	160	210	4,367	368

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Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group I (cont)	04/21/00	161	210	4,222	355
	04/22/00	162	208	4,222	352
	04/23/00	163	207	4,367	362
	06/06/00	169	135	246	13
	06/07/00	170	135	1,722	93
	06/08/00	171	130	1,640	85
	07/25/00	184	252	1,200	121
	07/26/00	185	252	2,000	202
	07/27/00	186	251	2,400	241
	07/28/00	187	251	2,900	292
	07/29/00	188	250	3,000	301
	07/30/00	189	250	3,200	321
	07/31/00	190	249	3,300	329
Well Group II	08/01/00	191	248	4,316	429
- RW-5	08/02/00	192	249	4,316	431
Brought Online	08/03/00	193	249	4,316	431
	08/04/00	194	245	3,935	386
	08/05/00	195	248	3,935	391
	08/06/00	196	248	3,935	391
	08/07/00	197	255	3,681	376
	08/12/00	199	250	2,539	254
	08/13/00	200	248	3,808	379
	08/14/00	201	248	4,062	404
	08/15/00	202	248	4,062	404
	08/16/00	203	248	4,062	404
	08/17/00	204	248	4,062	404
	08/18/00	205	248	3,935	391
	08/19/00	206	248	3,935	391
	08/20/00	207	248	3,935	391
	08/21/00	208	248	3,808	379
	08/22/00	209	248	3,681	366
	08/23/00	210	248	3,681	366
	08/24/00	211	247	3,681	364
	08/25/00	212	247	3,554	352
	08/26/00	213	246	3,554	350
	08/27/00	214	246	3,427	338
	08/28/00	215	247	3,300	327
	08/29/00	216	247	3,173	314
	08/30/00	217	248	3,046	303
	08/31/00	218	247	3,046	302
	09/01/00	219	246	3,173	313
	09/02/00	220	249	2,920	291
	09/03/00	221	247	3,046	302
	09/04/00	222	247	3,046	302
	09/05/00	223	247	3,046	302
	09/06/00	224	247	3,046	302
	09/07/00	225	246	3,046	300
	09/08/00	226	243	3,300	321
	09/09/00	227	237	3,935	374
	09/10/00	228	237	3,935	374
	09/11/00	229	236	3,935	372

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
<u>Well Group II (cont)</u>	09/12/00	230	236	3,935	372
	09/13/00	231	249	4,062	405
	09/14/00	232	248	4,062	404
	09/15/00	233	249	3,554	355
	09/16/00	234	249	3,046	304
	09/17/00	235	249	3,046	304
	09/18/00	236	249	3,046	304
	09/19/00	237	249	3,046	304
	09/20/00	238	249	2,793	279
	09/21/00	239	249	2,793	279
	09/22/00	240	249	2,666	266
	09/23/00	241	247	2,031	201
	09/24/00	242	249	1,396	139
	09/25/00	243	240	3,808	366
	09/26/00	244	241	3,935	380
	09/27/00	245	240	3,808	366
	09/28/00	246	239	3,681	353
	09/29/00	247	239	3,427	328
	09/30/00	248	240	3,427	330
	10/01/00	249	225	2,129	192
	10/02/00	250	223	1,730	155
	10/03/00	251	223	1,596	143
	10/04/00	252	221	931	82
	10/05/00	253	219	532	47
	10/06/00	254	237	3,459	329
	10/07/00	255	235	3,459	326
	10/08/00	256	235	3,459	326
	10/09/00	257	232	3,060	285
	10/10/00	258	231	2,528	234
	10/11/00	259	232	2,129	198
	10/12/00	260	232	2,129	198
	10/13/00	261	238	3,459	330
	10/14/00	262	237	3,193	303
	10/15/00	263	234	2,661	250
	10/16/00	264	232	2,262	210
	10/17/00	265	231	2,129	197
	10/18/00	266	230	2,129	196
	10/19/00	267	230	2,262	209
	10/20/00	268	239	3,326	319
	10/21/00	269	232	3,193	297
	10/22/00	270	227	2,528	230
	10/23/00	271	221	1,064	94
	10/24/00	272	219	532	47
	10/25/00	273	217	266	23
	10/26/00	274	215	133	11
	10/27/00	275	228	2,661	243
	10/28/00	276	228	2,395	219
	10/29/00	277	222	1,596	142
	10/30/00	278	217	133	12
	10/31/00	279	215	133	11
	11/01/00	280	217	204	18

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group II (cont)					
11/02/00	281	215	102	9	
11/03/00	282	228	2,555	233	
11/04/00	283	228	1,840	168	
11/05/00	284	222	1,226	109	
11/06/00	285	217	1,022	89	
11/07/00	286	215	102	9	
11/08/00	287	226	204	19	
11/09/00	288	228	204	19	
11/10/00	289	228	102	9	
11/11/00	290	224	1,431	128	
11/12/00	291	223	1,431	128	
11/13/00	292	230	1,226	113	
11/14/00	293	228	1,022	93	
11/15/00	294	234	613	58	
11/16/00	295	225	1,022	92	
11/17/00	296	225	1,226	111	
11/18/00	297	230	1,635	151	
11/19/00	298	230	1,431	132	
11/20/00	299	230	1,226	113	
11/21/00	300	230	1,022	94	
11/22/00	301	227	1,226	112	
11/23/00	302	221	818	72	
11/24/00	303	225	409	37	
11/25/00	304	222	204	18	
11/26/00	305	230	102	9	
11/27/00	306	225	2,044	184	
11/28/00	307	228	1,840	168	
11/29/00	308	222	1,226	109	
11/30/00	309	223	102	9	
12/01/00	310	234	1,393	131	
12/02/00	311	230	2,136	197	
12/03/00	312	226	2,508	227	
12/07/00	315	235	2,508	236	
12/08/00	316	234	2,415	227	
12/09/00	317	232	2,136	199	
12/10/00	318	231	1,765	163	
12/11/00	319	232	1,486	138	
12/18/00	322	147	2,880	170	
12/19/00	323	141	2,972	168	
12/20/00	324	142	2,972	169	
12/21/00	325	144	3,065	177	
12/22/00	326	139	2,044	114	
12/23/00	327	128	2,322	119	
12/24/00	328	121	1,951	95	
12/25/00	329	121	1,951	95	
12/26/00	330	123	2,044	101	
12/27/00	331	123	2,044	101	
12/28/00	332	121	1,951	95	
12/29/00	333	122	2,044	100	
12/30/00	334	121	1,951	95	
12/31/00	335	120	1,858	89	

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group II (cont)					
01/01/01	336	118	1,858	88	
01/02/01	337	120	1,951	94	
01/03/01	338	120	1,951	94	
01/07/01	342	118	1,858	88	
01/08/01	343	115	1,393	64	
01/09/01	344	114	1,115	51	
01/10/01	345	115	1,208	56	
01/11/01	346	116	1,300	60	
01/12/01	347	115	1,579	73	
01/13/01	348	117	1,486	70	
01/14/01	349	117	1,208	57	
01/15/01	350	114	1,115	51	
01/16/01	351	115	1,022	47	
01/17/01	352	119	1,300	62	
01/18/01	353	119	1,300	62	
01/19/01	354	117	1,300	61	
01/20/01	355	117	1,486	70	
01/21/01	356	117	1,486	70	
01/22/01	357	120	1,765	85	
01/23/01	358	122	1,951	95	
01/24/01	359	116	1,300	60	
01/25/01	360	114	1,115	51	
01/26/01	361	114	743	34	
01/27/01	362	113	650	29	
01/28/01	363	114	929	42	
01/29/01	364	113	929	42	
01/30/01	365	113	836	38	
01/31/01	366	114	929	42	
02/01/01	367	115	1,964	91	
02/02/01	368	116	2,321	108	
02/03/01	369	117	3,035	142	
02/04/01	370	124	4,284	213	
02/05/01	371	130	4,641	242	
02/06/01	372	131	5,177	272	
02/07/01	373	128	3,213	165	
02/08/01	374	130	3,213	167	
02/09/01	375	121	3,035	147	
02/10/01	376	122	3,035	148	
02/11/01	377	124	3,035	151	
02/12/01	378	125	3,213	161	
02/13/01	379	125	3,213	161	
02/14/01	380	125	3,213	161	
02/15/01	381	125	3,035	152	
02/16/01	382	125	2,856	143	
02/17/01	383	125	2,856	143	
02/18/01	384	125	2,678	134	
02/19/01	385	125	2,499	125	
02/20/01	386	125	2,499	125	
02/21/01	387	125	2,321	116	
02/22/01	388	125	2,142	107	
02/23/01	389	125	1,964	98	

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group II (cont)					
02/24/01	390	125	1,785	89	
02/25/01	391	125	1,785	89	
02/27/01	393	125	3,392	170	
02/28/01	394	125	3,392	170	
03/01/01	395	219	3,491	306	
03/02/01	396	218	3,658	320	
03/03/01	397	217	3,658	318	
03/04/01	398	219	3,491	306	
03/05/01	399	219	3,491	306	
03/06/01	400	218	3,491	305	
03/07/01	401	222	3,159	281	
03/08/01	402	221	3,325	295	
03/09/01	403	221	3,325	295	
03/10/01	404	222	2,826	251	
03/11/01	405	218	2,494	218	
03/20/01	408	232	1,496	139	
03/21/01	409	237	3,325	316	
03/27/01	412	243	1,995	194	
03/28/01	413	243	3,824	372	
03/29/01	414	242	4,489	435	
04/01/01	415	240	83	8	
04/02/01	416	242	83	8	
04/03/01	417	236	662	63	
04/04/01	418	225	827	75	
04/05/01	419	220	83	7	
04/17/01	422	250	496	50	
04/18/01	423	244	662	65	
04/19/01	424	234	662	62	
04/24/01	427	213	993	85	
04/25/01	428	217	1,820	158	
04/26/01	429	218	2,151	188	
04/27/01	430	219	2,234	196	
04/28/01	431	219	2,234	196	
04/29/01	432	218	2,068	181	
04/30/01	433	219	1,820	160	
05/01/01	434	217	1,539	134	
05/02/01	435	217	1,539	134	
05/03/01	436	208	62	5	
05/08/01	437	202	862	70	
05/09/01	438	201	1,846	149	
05/22/01	441	254	2,093	213	
05/30/01	444	263	1,169	123	
05/31/01	445	271	1,292	140	
06/01/01	446	271	3,657	397	
06/05/01	449	268	3,831	412	
06/06/01	450	263	4,180	441	
06/07/01	451	258	4,006	414	
06/08/01	452	226	4,006	363	
06/09/01	453	202	3,831	310	
06/10/01	454	201	3,831	309	
06/11/01	455	200	4,180	335	

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
<u>Well Group II (cont)</u>	06/12/01	456	196	4,006	315
	06/13/01	457	189	4,006	303
	06/14/01	458	177	4,180	297
	06/15/01	459	180	4,180	302
	06/16/01	460	184	4,180	308
	06/17/01	461	189	4,180	317
	06/18/01	462	192	4,354	335
	06/19/01	463	191	4,180	320
	06/20/01	464	191	4,180	320
	06/21/01	465	190	4,180	318
	06/22/01	466	191	4,354	333
	06/23/01	467	194	4,354	339
	06/24/01	468	196	4,354	342
	06/25/01	469	201	4,528	365
	06/26/01	470	196	4,354	342
	06/27/01	471	195	4,354	340
	06/28/01	472	195	4,354	340
	06/29/01	473	196	4,354	342
	06/30/01	474	195	4,354	340
	07/01/01	475	196	1,184	93
	07/02/01	476	198	1,137	90
	07/03/01	477	193	1,137	88
	07/04/01	478	194	1,137	88
	07/05/01	479	195	1,137	89
	07/06/01	480	195	1,137	89
	07/07/01	481	195	1,137	89
	07/08/01	482	195	1,137	89
	07/09/01	483	195	1,089	85
	07/10/01	484	197	1,184	93
	07/11/01	485	194	1,184	92
	07/12/01	486	194	1,184	92
	07/13/01	487	193	1,184	92
	07/14/01	488	198	1,184	94
	07/15/01	489	190	1,184	90
	07/16/01	490	186	1,184	88
	07/17/01	491	169	1,326	90
	07/18/01	492	166	1,373	91
	07/19/01	493	162	1,326	86
	07/20/01	494	160	1,326	85
	07/21/01	495	158	1,326	84
	07/22/01	496	159	1,373	88
	07/23/01	497	157	1,373	86
	07/24/01	498	161	616	40
	07/25/01	499	161	710	46
	07/26/01	500	159	663	42
	07/27/01	501	162	710	46
	07/28/01	502	162	710	46
	07/29/01	503	163	710	46
	07/30/01	504	163	710	46
	07/31/01	505	161	710	46
	08/02/01	507	162	1,265	82

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group II (cont)	08/03/01	508	162	1,355	88
	08/04/01	509	162	1,355	88
	08/05/01	510	163	1,355	89
	08/06/01	511	163	1,355	89
	08/07/01	512	165	1,355	90
	08/08/01	513	167	1,355	91
	08/09/01	514	166	1,355	90
	08/10/01	515	167	1,355	91
	08/11/01	516	167	1,355	91
	08/12/01	517	165	1,355	90
	08/13/01	518	163	1,355	89
	08/14/01	519	167	1,355	91
	08/15/01	520	187	1,174	88
	08/16/01	521	165	1,355	90
	08/17/01	522	168	1,355	91
	08/18/01	523	170	1,355	92
	08/19/01	524	174	1,355	95
	08/20/01	525	176	1,265	89
Well Group III	09/04/01	532	620	3,300	820
- RW-3, 4, 6, 7	09/10/01	533	515	2,078	429
Brought Online	09/17/01	540	470	3,520	663
- New SVE Unit	09/24/01	547	450	3,520	635
Brought Online	10/08/01	547	545	569	124
	10/13/01	552	535	1,990	427
	10/18/01	555	660	2,970	786
	10/22/01	556	520	1,650	344
	10/29/01	562	480	3,630	698
	11/05/01	563	468	1,920	360
	11/12/01	567	472	920	174
	11/19/01	570	490	2,310	454
	11/26/01	573	470	1,480	279
	12/03/01	580	481	2,420	467
	12/10/01	586	419	1,110	186
	12/17/01	592	465	712	133
	12/27/01	593	485	910	177
	01/28/02	602	456	2,530	462
	02/04/02	609	485	2,420	470
	02/11/02	616	490	1,980	389
	02/18/02	623	500	1,980	397
	03/11/02	639	485	1,700	330
	03/18/02	646	491	1,850	364
	03/25/02	653	491	1,760	346
	04/01/02	660	469	1,870	352
	04/08/02	667	484	1,980	384
	04/15/02	674	478	1,870	358
	04/22/02	680	490	1,980	389
	04/29/02	687	490	1,980	389
	06/03/02	706	448	2,420	435
	06/10/02	713	467	2,090	391
	06/17/02	720	460	2,420	446
	06/24/02	728	480	3,080	593

Table E-1
Soil Vapor Extraction System Field Data
and Least-Squares Regression Analysis
Mission Valley Terminal, San Diego, CA
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Well Group Startup	Date	Days of Operation	Diluted Flow Rate (scfm)	Diluted VOC Influent Concentration ⁽¹⁾ (ppmv)	VOC Mass Extracted ⁽²⁾ (pounds/day)
Well Group III (cont)	07/01/02	735	480	2,200	423
	07/08/02	741	469	2,310	434
	09/23/02	752	512	1,320	271
	09/30/02	763	490	2,090	410
	10/09/02	768	500	2,090	419
	10/16/02	775	486	1,650	321
	10/23/02	783	530	810	172
	11/01/02	792	518	630	131
	11/14/02	802	490	2,200	432
	11/19/02	807	480	1,650	317
	11/26/02	814	340	2,200	300
	12/03/02	818	487	2,200	429
	12/12/02	827	470	1,650	311
	12/30/02	835	474	2,200	418
	02/20/03	854	470	1,100	207
	02/25/03	859	467	2,750	515
	03/03/03	865	470	2,200	414
	03/12/03	874	456	1,100	201
	04/17/03	883	477	1,100	210
	04/22/03	888	475	1,100	209
	05/12/03	899	478	2,200	422
Well Group IV - Phase I Expansion Brought Online	06/16/03	904	497	4,400	877
	06/18/03	906	506	4,400	892
	06/23/03	911	512	4,950	1,016
	07/09/03	922	519	3,500	728
	07/17/03	925	487	3,850	752
	07/24/03	933	472	4,400	832
	08/07/03	940	478	3,850	738
	08/21/03	950	372	4,400	656
	08/25/03	954	390	3,300	516
	09/08/03	960	360	4,400	635
	09/19/03	966	396	5,500	873
	09/23/03	970	395	5,500	871
	09/25/03	973	401	5,500	884
	09/30/03	977	390	5,500	860
	10/02/03	979	400	5,500	882
	10/07/03	984	395	5,500	871
	10/14/03	991	365	4,400	644
	10/16/03	993	365	4,400	644
	10/21/03	998	390	3,300	516
	10/31/03	1000	385	4,400	679
	11/04/03	1004	395	4,400	697
	11/11/03	1011	405	4,400	714
	11/17/03	1018	375	3,300	496

Notes:

VOC - Volatile Organic Compound

(1) Volumetric concentration as total VOC.

(2) Extracted mass of VOC based on an assumed molecular weight of 100.

(3) Least-Squares Regression Analysis fitted to the equation: $y = ae^{-bt}$

Table E-2
Soil Vapor Extraction Well Vapor Sample Analytical Results
 Mission Valley Terminal, San Diego, CA
 LFR 002-10180-13

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Well Sampled	Date Sampled	Volatile Fuel Hydrocarbons (C6-C12)	Benzene	MTBE	Benzene Mass Fraction	MTBE Mass Fraction
		EPA 8015B/8021B				
		(mg/m ³)	(mg/m ³)	(mg/m ³)	(ratio)	(ratio)
Arithmetic Average					0.028	0.007
Lower 97.5% Confidence Limit					0.025	0.005
RW-10	04/10/03	5300	110	5 *	0.021	0.001
	04/17/03	49000	1300	25 *	0.027	0.001
	11/18/03	51000	1200	390	0.024	0.008
RW-11	04/10/03	890	25	5 *	0.028	0.006
	04/17/03	3800	68	5 *	0.018	0.001
RW-12	04/10/03	440	14	5 *	0.032	0.011
	04/17/03	69000	1500	50 *	0.022	0.001
	10/14/03	3900	130	110	0.033	0.028
	10/21/03	48000	1600	1200	0.033	0.025
	10/31/03	36000	1600	880	0.044	0.024
	11/04/03	36000	1600	810	0.044	0.023
	11/18/03	33000	1200	520	0.036	0.016
RW-13	04/10/03	7600	230	5 *	0.030	0.001
	04/17/03	38000	1200	50 *	0.032	0.001
	10/14/03	28000	680	140	0.024	0.005
	10/21/03	36000	930	180	0.026	0.005
	10/31/03	21000	920	200	0.044	0.010
	11/04/03	19000	840	200	0.044	0.011
	11/18/03	30000	900	380	0.030	0.013
RW-14	04/10/03	15000	630	5 *	0.042	0.000
	04/17/03	21000	720	25 *	0.034	0.001
RW-15	04/10/03	7200	210	5 *	0.029	0.001
	04/17/03	27000	590	25 *	0.022	0.001
RW-16	04/10/03	1000	32	5 *	0.032	0.005
	04/17/03	30000	500	58	0.017	0.002
	10/14/03	16000	130	25 *	0.008	0.002
	10/21/03	15000	99	25 *	0.007	0.002
	10/31/03	9100	190	25 *	0.021	0.003
	11/04/03	9500	170	25 *	0.018	0.003
	11/18/03	13000	140	25 *	0.011	0.002
RW-17	04/10/03	1500	62	5 *	0.041	0.003
	04/17/03	110000	2400	550	0.022	0.005
	10/14/03	49000	1100	210	0.022	0.004
	10/21/03	47000	1100	160	0.023	0.003
	10/31/03	18000	760	150	0.042	0.008
	11/04/03	28000	1200	210	0.043	0.008
	11/18/03	36000	910	130	0.025	0.004
RW-18	04/10/03	900	31	5 *	0.034	0.006
	04/17/03	31000	750	100	0.024	0.003
	10/14/03	3100	16	3 *	0.005	0.001
	10/21/03	2000	25 *	25 *	0.013	0.013
	10/31/03	2200	70	25 *	0.032	0.011
	11/04/03	870	11	3 *	0.013	0.003
	11/18/03	920	7.8	3 *	0.008	0.003
RW-19	04/08/03	2100	35	5 *	0.017	0.002
	04/10/03	530	19	5 *	0.036	0.009
	04/17/03	92000	2100	270	0.023	0.003
	09/18/03	77000	1300	380	0.017	0.005
	10/14/03	76000	2600	1100	0.034	0.014
	10/21/03	81000	2900	1300	0.036	0.016
	10/31/03	64000	3700	1100	0.058	0.017
	11/04/03	57000	3200	1100	0.056	0.019
	11/18/03	65000	2800	1100	0.043	0.017
RW-20	04/09/03	2700	56	5 *	0.021	0.002
	04/10/03	2000	75	5 *	0.038	0.003
	04/17/03	140000	2500	820	0.018	0.006
	08/25/03	80000	NA	NA	---	---
	09/18/03	32000	NA	NA	---	---
	10/14/03	87000	2700	1100	0.031	0.013
	10/21/03	79000	2500	1000	0.032	0.013
	10/31/03	62000	3200	840	0.052	0.014
	11/04/03	12000	550	180	0.046	0.015
	11/18/03	57000	1900	470	0.033	0.008
RW-22A	11/04/03	20000	650	50 *	0.033	0.003
RW-23A	11/03/03	38000	1300	180	0.034	0.005
RW-24A	11/04/03	49000	1400	100 *	0.029	0.002
RW-25A	11/03/03	83000	2900	860	0.035	0.010
RW-26A	11/04/03	43000	1200	79	0.028	0.002
RW-27A	11/04/03	110000	4100	250 *	0.037	0.002
RW-28A	11/05/03	74000	800	200 *	0.011	0.003
RW-29A	11/06/03	120000	2000	125 *	0.017	0.001
RW-30A	11/05/03	32000	410	50 *	0.013	0.002
RW-31	11/05/03	120000	3800	400 *	0.032	0.003
RW-32	11/07/03	130000	2500	125 *	0.019	0.001
RW-33	11/07/03	97000	810	50 *	0.008	0.001
RW-34A	11/06/03	25000	340	25 *	0.014	0.001

NA = Not Analyzed

* Not Detected at Reporting Limit, value shown is half of the reporting limit.

Table E-3
Best Estimate Mass Reduction by SVE Model
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

SVE System Parameters	Well Group II	Well Group III	Well Group IV	Well Group V	Mass Estimate (Unsaturated Soil Only)		Vapor Extraction Mass Fraction		Target Mass Fraction		Estimated Time to Achieve Target Mass Fraction	
					(pounds)				(ratio)			
No. of SVE Wells	1	4	11	12	TPH	601,794						
Normalized Rate Constant, <i>a</i> (pound/day)	105	85	53	81	Benzene	4,706	Benzene	0.028	Benzene	4.83E-05	Benzene	
Time Constant, <i>b</i> (1/day)	-1.30E-03	-7.95E-04	-3.61E-03	-1.90E-03	MTBE	1,269	MTBE	0.007	MTBE	7.60E-05	MTBE	

Table E-4
Conservative Estimate Mass Reduction by SVE Model
Mission Valley Terminal, San Diego, CA
LFR 002-10180-13

SVE System Parameters	Well Group II	Well Group III	Well Group IV	Well Group V	Mass Estimate (Unsaturated Soil Only)	Vapor Extraction Mass Fraction	Target Mass Fraction		Estimated Time to Achieve Target Mass Fraction	
					(pounds)					
No. of SVE Wells	1	4	11	12	TPH	759,537				
Normalized Rate Constant, <i>a</i> (pound/day)	105	85	53	53	Benzene	7,618	Benzene	0.025	Benzene	4.83E-05
Time Constant, <i>b</i> (1/day)	-1.30E-03	-7.95E-04	-3.61E-03	-3.61E-03	MTBE	2,294	MTBE	0.005	MTBE	7.60E-05
									MTBE	946

Figure E-1
Measured Mass Extraction Rate v. Operation Time
and Least Square Regression Analysis Curve Fit
 Mission Valley Terminal, San Diego, California

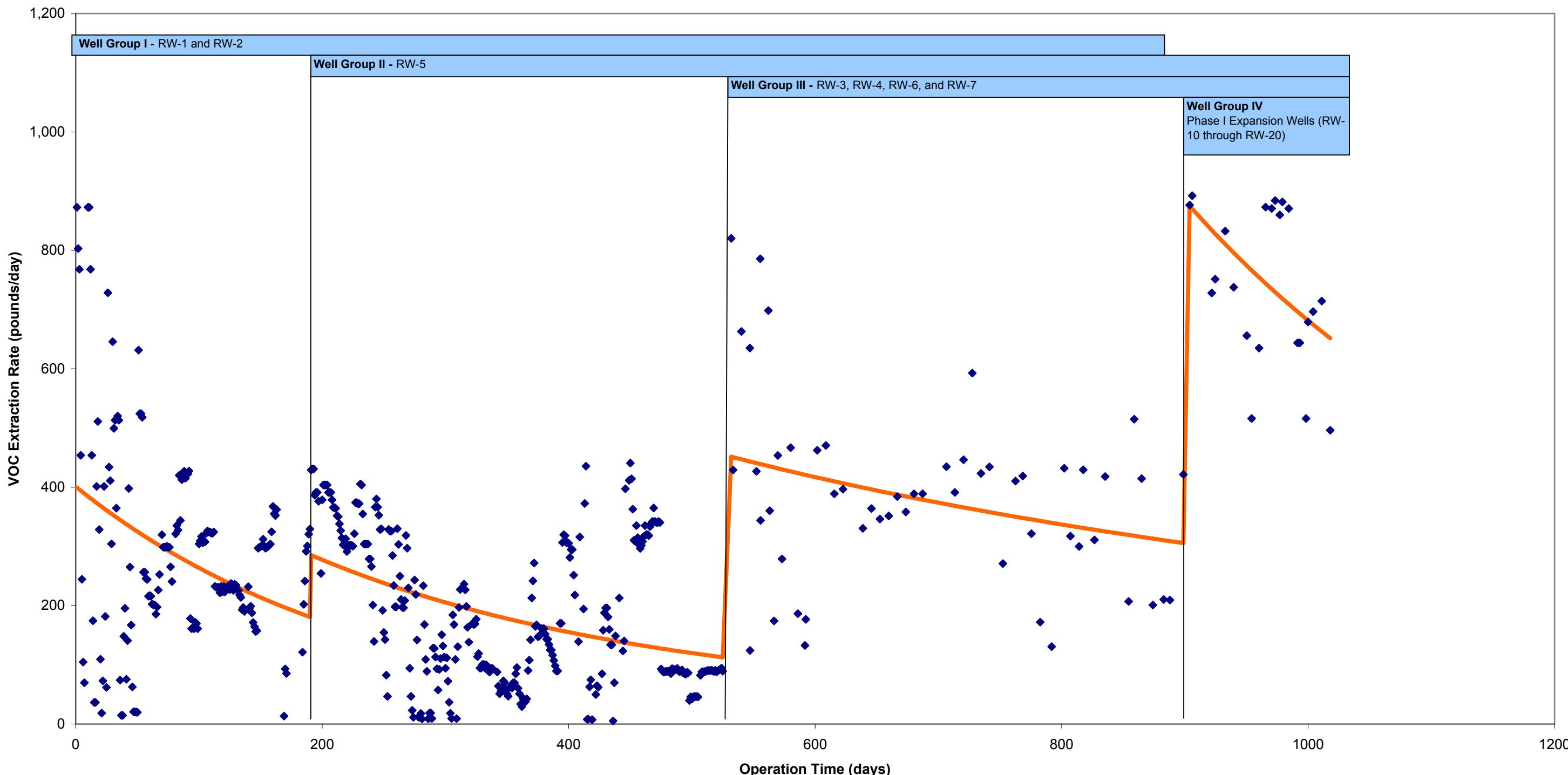


Figure E-2
Best Estimate Mass Reduction by SVE Model
Mission Valley Terminal, San Diego, California

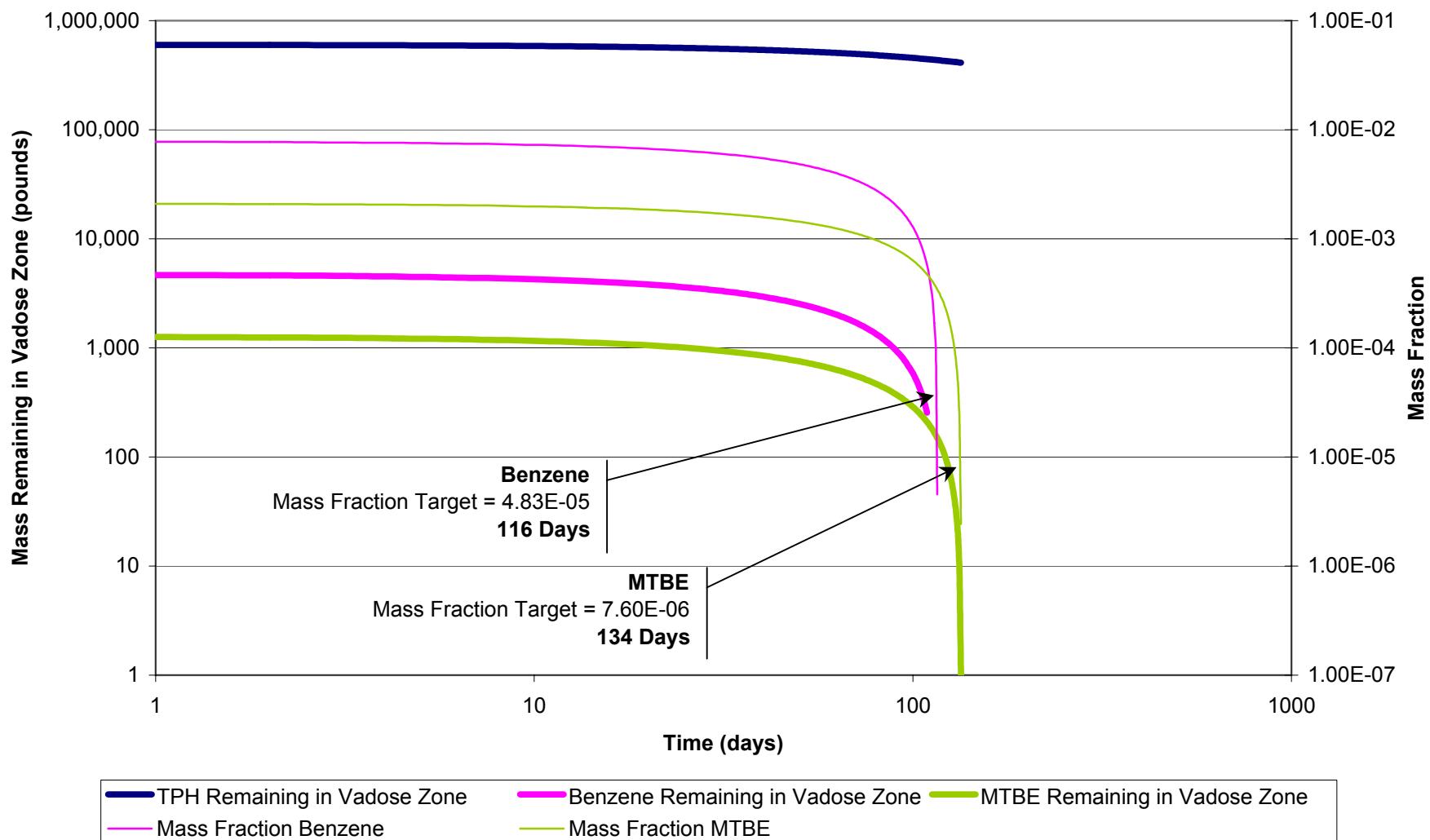


Figure E-3
Conservative Estimate Mass Reduction by SVE Model
 Mission Valley Terminal, San Diego, California

